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再论板块位移的生物效应*
——掸邦－马来亚板块位移对高黎贡山生物区系的影响

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摘要: 本文在《掸邦－马来亚板块位移对独龙江植物区系的生物效应》一文的基础上, 将研究范围扩大到高黎贡山的生物区系, 再次论板块位移的生物效应。结果表明, 板块位移 对高黎贡山以及东喜马拉雅和云贵高原的植物区系和动物区系的演化和分布都产生了明显的隔离影响, 形成了高黎贡山独特的生物多样性。

关键词: 板块位移; 生物效应; 掸邦－马来亚板块; 高黎贡山
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Re－examination of the Biological Effect of Plate Movement
——Impact of Shan－Malay Plate Displacement (the Movement of Burma－Malaya Geoblock) on the Biota of the Gaoligong Mountains

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Abstract: This paper is developed from the previous publication, *Biological Effect of Shan－Malay Plate Displacement* (*the Movement of Burma－Malaya Geoblock*) *on Dulong River Flora* (published in this journal in 1994. After more than four years of careful study, we have expanded the scope to some of the flora and fauna of the Gaoligong Mountains and then to the biota of the East Himalayas and the Yunnan－Guizhou Plateau. The results from this re－examination of the biological effects of plate movement indicate that plate displacement had a series of isolating geographical effects on the occurrence, evolution, and distribution of the flora and fauna in this region, resulting in the Gaoligong Mountains becoming an area with a distinct and divers biota which is ancestral to the biota of the East Himalayas.

Key words: Plate movement; Biological effect; Shan－Malay Plate; Gaoligong Mountains

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1 Introduction

The Himalayas movement, occurring in the middle to late Tertiary Period, is the most recent large – scale neotectonics in the world and has greatly changed the surface configuration of Asia including connection of the Eurasian Continent with the Gondwanan India Plate, the rise of the Qinghai – Tibetan Plateau, disappearance of the Tethys sea, creation of the Himalayas, and contact between the biota in the tropical area of Asia and that of East Asia (Wu & Wang, 1983). The resulting system of high mountains and deep gorges such as the east – west Himalayas; the north – south Hengduan Mountains; the gorges of the Nujiang (Salween), Lancang (Mekong), and Chang Jiang (Yangtze); the NNW – SSE Ailao Mountain system; and the Yuanjiang River – Honghe River (the Red River) Valley all became natural barriers to prevent organism from spreading. Because of the displacement of the Gaoligong Mountains by the neotectonics, the environment of this region became more complicated and the topography more isolated (Figure 1). The creation of this distinct ecological system was caused by the Shan – Malay Plate displacement.

From 1989 to 1993 the senior author undertook an intensive study in the Dulong (also called Drung) River region of Yunnan Province, proposed that this region is the cradle of the East Asian biota, and also discussed the biological effect of Shan – Malay Plate displacement (called "the movement of Burma – Malaya geoblock" in the previous publication) on this area (Li, 1994). In order to further investigate and analyze the biological effect of the plate displacement, we have expand the scope of this earlier study to include the whole Gaoligong Mountains range and also consider not only plants but also mammals and fish. However, there are major gaps in the available data due to inadequate biological surveys, specifically the western slopes of the Gaoligong Mountains in Myanmar to the west, the region from the northern end of the Gaoligong Mountains across northern Myanmar to the south slopes of the Himalayas as far as Bhutan and eastern Nepal, and the Yunnan – Guizhou Plateau to east. Even with these limitation we hope that this paper will increase our understand of the biogeography of the Gaoligong Mountains region and benefit biogeographic research in neighboring areas such as East Asia, the Qinghai – Tibetan Plateau, and the East Himalayas.

2 Brief introduction to history of Shan – Malay Plate displacement

The Gaoligong Mountains cover a north – south range of more than 600 km (5 degrees latitude) from the Tibetan Plateau in the north and along the Myanmar border to southwest Yunnan in the south. This mountain range belongs to the northern section of the West Yunnan – Shan – Malay Plate (Figure 1) (Chang & Cheng, 1995). The Shan – Malay Plate was once the edge of Gondwanaland and for its early history was in the southern hemisphere. Starting in the Triassic Period this plate drifted slowly to the northern hemisphere and was close to the Yangtze Plate which was drifting northward from near the equator (Figure 2) (Chang & Cheng, 1995). After the Triassic Period Gondwanaland disintegrated and the Baoshan Microplate separated from Gondwanaland, drifted northeastward, and fused with the Yangtze Continemtal Plate. Concurrently the Tengchong – Lianghe area rose to become dry land. Subsequently the Nujiang River area and the Lancang River area rose and also became dry land, and the

Dulong River area and Tengchong – Lianghe area connected with the Eurasian Continent. During the early Eocene epoch or later in the Tertiary Period, the Indian Plate collided to the Eurasian Continental Plate and thrust under it at an angle of 10℃ ~ 15℃, causing the this region of the Eurasian Plate to rise. During the thrusting process, a clockwise directional force resulted from a backward resistant force caused by the Yangtze Plate and friction from the rising region of the Irrawaddy River, made the landmass on the eastern side fracture in the regions of the Longchuan River, Daying River, and Dulong River and rotate rightward, causing the region of the Dulong River as well as the Myanmar landmass to move northward at least 450 km (Chang & Cheng, 1995).

The Gongshan area, Fugong area, and the lower regions of the Yuanjiang River to the north of the Gaoligong Mountains were located at the same latitude before the Miocene. The rightward rotation made the Gaoligong Mountains area move northward over 450 km, equivalent to 4.5° latitude. This means that prior to and at the beginning of orogenesis the Gaoligong Mountains were located 450 km to the south of their existing position. The present latitude of Gongshan County ranges from 27°40′ to 28°50′ N which suggests that the location of the county in Miocene should be at 23°to 24° N. Luchun and Jingping counties in the northeast of the Indo – China Plate are located at the east end of the rightward

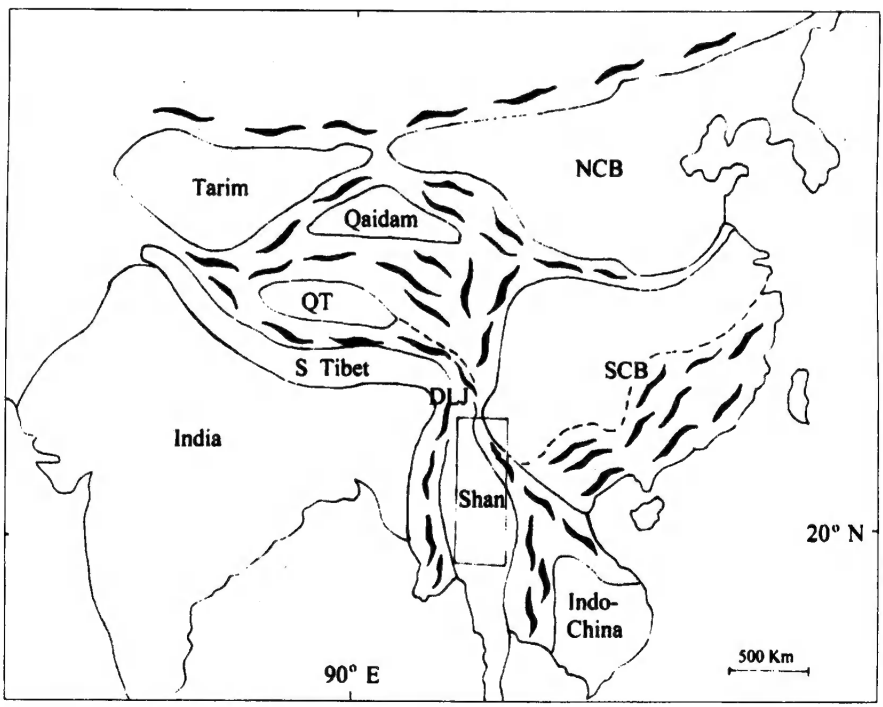

Fig.1 Sketch of the tectonic elements of Sountheast Asia

SCB: south of China Geoblock; NCB: North of China Geoblock; Tarim: Tarim Geoblock; Qiandam: Qiandam Geoblock; QT: Qingzang Geoblock; S Tibet: South Tibet Geoblock; Shan: Shan – Malayan Geoblock; Indo – China: Indo – China Geoblock; India: India Geoblock; DLJ: Dulong River, North of Shan – Malayan Geoblock ancient geomangetism sampling place in rectangle (After Zhang, 1995)

rotation axis, far away from subduction region, so their displacement is comparably small, about 1° ~ 2° latitude. The Luchun – Jingping area is now situated at 22°22′ to 23°N, so it would have been at about 24° N. The area from Myitkyina in Myanmar to Tengchong County to the south of the Gaoligong Mountains (now at 24°30′ to 26°N) would have been to the south of the Tropic of Cancer before displacement and would once have be covered with typical moist tropical forests and vegetation. After displacement, the two areas which once were at the same latitude are now 4° ~ 5° apart in latitude. Hence great difference in the ecological environment occurred between these two areas. The Gaoligong Mountains in northwest Yunnan are now a north temperate environment, while such areas as Jingping, Hekou, and Malipo in southeast Yunnan still have a tropical environment. We propose that the northward displacement of the Shan – Malay Plate and the rightward rotation resulted in a series of complicated ecogeographical effects, causing the distinctive Gaoligong Mountains biota and the complex species distribution.

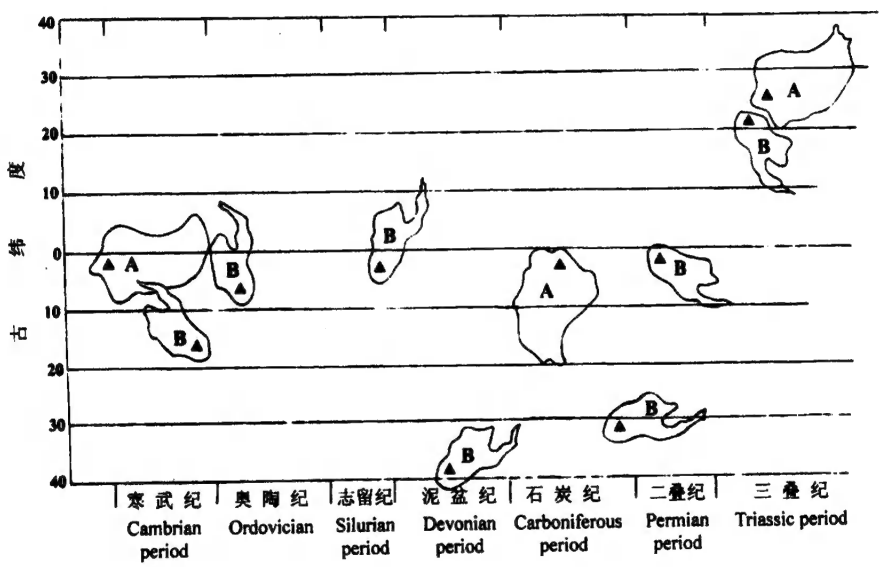

Fig.2 Cambrian Period – Triassic Period Paleoatitude diagram of Western Yunnan, China – Shan – Malayan Geoblock
A. Yantze Geoblock; B. Western Yunnan, China – Shan – Malayan Geoblock; ▲ Sampling Place (After Zhang L, 1995)

3 Biological effect of the Shan – Malay Plate displacement on the Gaoligong Mountains flora

3.1 Moist and broad – leaved evergreen trees in the subtropical zone replaced the Gandwanaland tropical vegetation as the tropical flora changed qualitatively into the existing subtropical East Asian flora

During the period of northward displacement and rightward rotation of the Shan – Malay Plate, the tropical climate in the Gaoligong Mountains area gradually turns into a subtropical climate, and the temperature in the valleys decreased by 5 ~ 6℃. The average long – tern temperature in the valleys in the Nujiang River area (Gongshan) is 7.9℃ less than that in the Hekou area. The extremely mini-

mum temperature is -1.5℃ in Gongshan County and 5.8℃ in Hekou County, thus the former is 7.3℃ lower than the latter. The average temperature in January in the Dulong River valley is also 5.4℃ lower than that in Hekou County (Yunnan Meteological Bureau, 1983; Ma, 1996; Ma *et al*, 1996). The change in climate resulted in disappearance of tropical rainforests and appearance of a moist broad-leaved evergreen forests and a north temperate East Asia type flora in the Dulong River and the Nujiang River valleys. This is in sharp contrast to the tropical rainforest vegetation that would have occured there in Tertiary Period and is still found in the Hekou area. Therefore, the plate displacement has caused an essential difference in terms of climate and biota between the Gaoligong Mountains area and southeast Yunnan. Only the distribution of some unique indicator plant can show the historical connection between the flora in these two areas. For example, the typical species of rainforest trees such as *Dipterocarpus tonkinensis* and *Hopea mollissina* have disappeared in the Gaoligong Mountains area, while the numerous typical trees which can be frequently seen in the broad-leaved evergreen forests along the Dulong River valley are *Cinnamomum*, *Cyclobalanopsis*, *Daphniphyllum*, *Garcinia*, *Lindera*, *Lithocarpus*, *Litsea*, *Randia*, *Rehderodendron*, *Schima*, *Symplocos*, *Ternstroemia*, *Wendlandia*, etc., most of which are represented by species spreading in the northern part of Myanmar and the Gaoligong Mountains area. This indicates that the flora has changed greatly. Today the only plants which prove the historical connection between the flora in the Gaoligong Mountains and that in Hekou area are some of the the trees, shrubs, epiphitic plants, and understory plants growing in the valleys.

3.2 Formation of an Ecological Diagonal controlling species distribution in Yunnan

The rotation caused by the collision of tectonic plates caused a clockwisely rotation of 10° ~ 70°, producing a series of rotation tectonics. The most prominent example is the huge turbine-like structure in the Nanjiang① A NNW-SSE ecological transition belt (called Ecological Diagonal in this paper) is formed along the Great Honghe fracture and the Ailao Mountains system. Within the west region of 21° to 27°N this Ecological Diagonal, the deformation, rotation, and displacement are the greatest. The Shan-Malay Plate rotated leftward by 25° ~ 30° and the Ailao Mountains fracture turned toward the left by 60° ~ 70°②. Because these plates were depressed in the east-west direction, stretched in the northsouth direction, and rotated and displaced, an Ecological Diagonal was formed from the northwest to the sountheast of Yunnan. The possibility of gene exchange for many species along the both sides of the Ecological Diagonal is restrained. The biogeographical effect caused by this is that some species are discontinuously distributed at both ends of the diagonal and some are concentrated on the sounthwest side. This diagonal becomes an isolation belt to sparate the biota in northeast Yunnan from that in southwest Yunnan.

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① Zhao Weicheng, Wei Chengjai, 1990. Study on Judgement and Reading of Satellite Imange Photoes of Fracture Structure in Yunnan Province, Scale: 1:500,000. Yunnan Institute of Geography.

② Cheng Liangzhong, 1994. Discussion on Geological Structure Background for Earthquakes in Yunnan. Yunnan Institute of Geology.

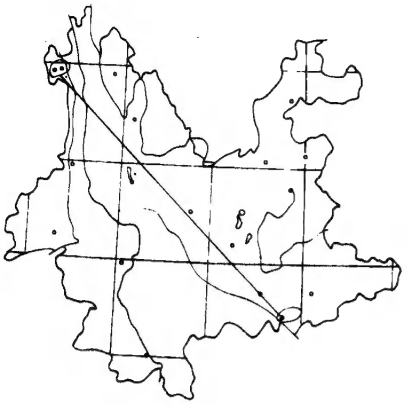

Fig.3 Disjuncted distribution of *Eurya inaequalis* (east and west slope of Gongshan – Pingbian)

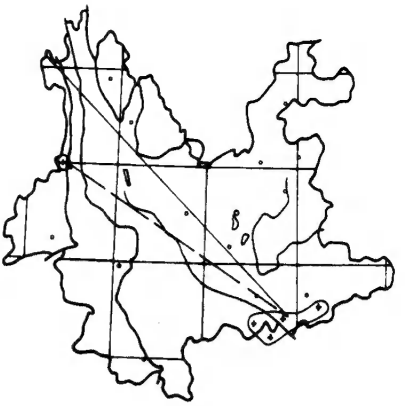

Fig.4 Disjuncted distribution of *Eurya perserrata* (Pianma – Jinping, Pingbian, Malipo, northern Vietnam. 1300 ~ 2000 m)

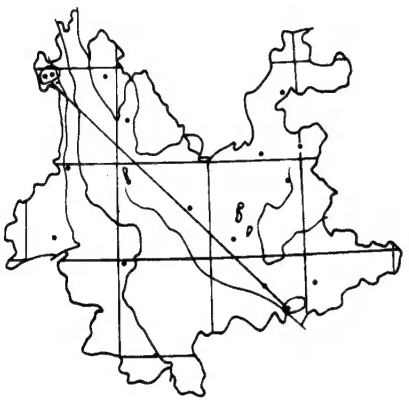

Fig.5 Disjuncted distribution of *Schima villosa* (Fugong – Jinping, Hekou, Pingbian)

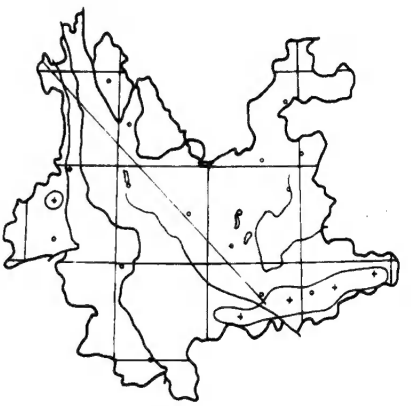

Fig.6 Disjuncted distribution of *Actinidia rubricaulis* (Tengchong – Pingbian, Lüchun, Mengzi, Wenshan, Xichou, Malipo, Funing)

3.2.1 **Distribution of species at both ends of the diagonal** Plate displacement resulted in change of the ecological environment, caused by the formation of the parallel high mountains and deep valleys in northwest Yunnan and the broad plains in Central Yunnan. The ecological isolation belt in large area was formed in the Gaoligong Mountains and the peripheral area surrounding the Yunnan Plateau, and the species exchange was eliminated between the Gaoligong Mountains and southeast Yunnan. The continuous distribution area of species prior to the plate displacement disappeared after displacement due to disappearance of available habitat on the diagonal because of the dry and cold climate of the Yunnan Plateau. The same species only remains at both ends of the diagonal, thus forming an interrupted northwest – southeast Yunnan distribution in Yunnan either completely restricted to Yunnan or extending from southeast Yunnan to north Vietnam or from northwest Yunnan to north Myanmar. Figures 3 ~ 8, 9:1, 10:1, 11, 12:2 show the distribution of 11 of these species.

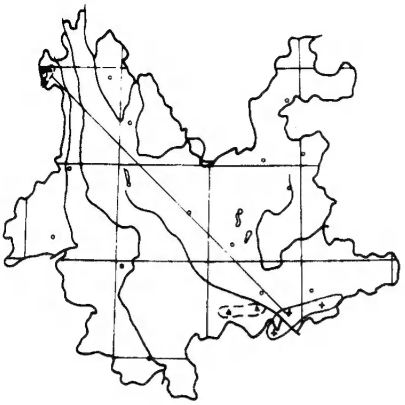

Fig.7 Disjuncted Vertical areas of Species in Yunnan
1. + *Medinilla petololii* (Dulongjiang of Gongshan – Pingbian, Xichou, Malipo 1000 ~ 1400 m)
2. ▲ *Sarcopyramis napelensis* var. *maculate* (east and west slope of Gongshan – Jinping, Lüchun. 2000 ~ 2300 m)

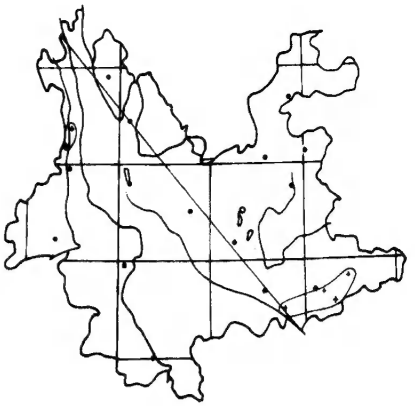

Fig.8 Disjuncted distribution of *Ilex longicandata* var. *glabra* (Fugong – Xichou, Pingbian, Guangnan, Malipo)

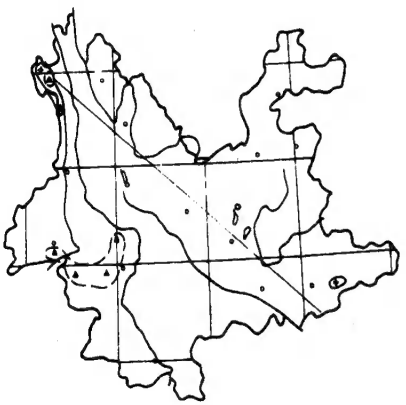

Fig.9 Disjucted vertical areas and Southwest area to the Ecological Diagonal of species in Yunnan
1. + *Aralia thomsonii* var. *glabrescens* (Gongshan, Fugong – Xichou. 1400 ~ 1600 m); 2. ▲ *Brassiopsis chenkangensis* (Gongshan, Zhenkang, Fengqing, Shuangjiang, Luxi. 1700 ~ 2400 m)

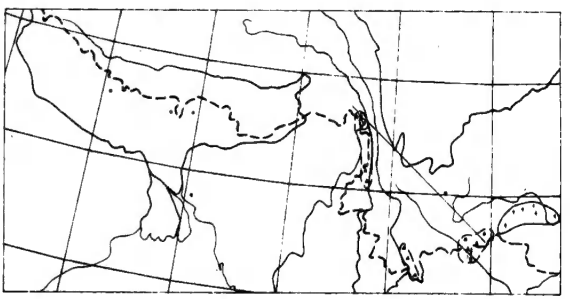

Fig.10 Disjuncted vertical areas and Southwest area of the Ecological Diagonal of Species in Yunnan
1. + *Ardisia ensifolia* (Gongshan – Funing, Lingyun, Tianlin, Du'n, Fengshan Bama, and gongcheng of Guangxi Province. 700 ~ 2300 m)
2. ▲ *Ardisia maculosa* (Gongshan, Baoshan, Simao, Jinhong, Mengla, Pingbian, Hekou, Maguan, Xichou, Malipo, northern Vietnam)

The pattern of plants distribution at both ends indicates that prior to the northward movement of the Gaoligong Mountains, some plants such as *Eurya inaequalis* and *Schima villosa* probably occupied a very large continuous distribution in Yunnan. Along with the northward movement of the Gaoligong Mountains, the tropical climate there gradually became subtropical. Moreover, on the rising Yunnan Plateau, the climate became cold and the precipitation decreased. The original conditions suitable for plants such as *E. inaequalis* and *S. villosa* disappeared in most of the Gaoligong Mountains area and

the Yunnan Plateau area, and many plant species disappeared. Today, some of them can only be found in the northern part (especially the east slopes) of the Gaoligong Mountains, located at the northeast end of the diagonal where the precipitation is plentiful all year around. The tropical ecological environment in Pingbian and Hekou at the southeast end of the diagonal remained largely unchanged before and after the movement of the plate so that *E. inaequalis* and *S. villosa* still grow in this area. Species showing this distrbution must be old species that predate the movement of the Gaoligong Mountains that occurred during the Miocene.

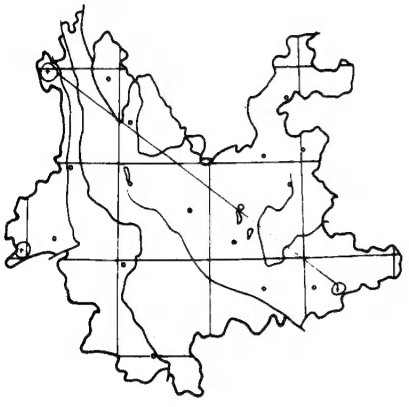

Fig.11 Disjuncted vertical areas and Sounthwest area to the Ecological Diagonal of *Huedendron tomentosum* (Gongshan – Ruili – Malipo)

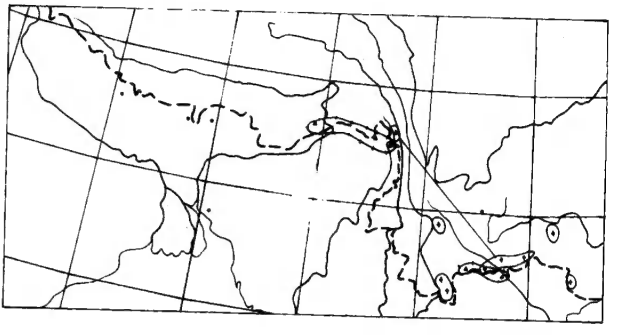

Fig.12 Disjuncted vertical areas and Sounthwest area of the Ecological Diagonal of species in Yunnan

1. + *Aeschynanthus austoyunnanensis* (Gongshan, Jinghong, Mengla, Jingdong, Jinping, Pingbian. Malipo; Fenglin, Longjin of GuangXi Province); 2. ▲ *Lysionotus waidii* W.W.Smith. (Motuo, Gongshan – lvchun, Hekou; north of Burma)

The plant distribution at both ends of the diagonal is due to factors of moisture and temperature. After moving to the north, the Gaoligong Mountains (especially the Gongshan and Fugong areas on the northern end the Gaoligong Mountains) is impacted by the southeast monsoons. The annual precipitation is great and the monthly rainfall is nearly the same all year around. As a result there is abundant moisture for plants. For instance, in February the precipitation is 279 mm in Bapuo on the Dulong River on the west slope and 148.7 mm in Fugong on the east slope. This amount of precipitation is much higher during this month than in Luchun (30.7 mm), Hekou (40.0 mm), and Jingping (45.3 mm). Some plants which originally grew in tropical areas still have sufficient moisture at the northern end of the Gaoligong Mountains after the displacement. In general the annual temperature in Gaoligong Mountains is lower than that in southeast Yunnan. In January, the temperature in Gaoligong Mountains is only half of that in Jingping and Hekou. Even at the lower elevations in the Gaoligong Mountains temperature in the coldest month is below 10℃. The result is that, although there is sufficient moisture for some species to have a disjunct distribution between the two areas, broad – leaved tropical trees are largely restricted to the southeast end of the Ecological Diagonal.

3.2.2 **Distribution of species on the southwest side of the Ecological Diagonal** There are species distributions that are restricted to the southwest side of the Ecological Diagonal, i. e. in sountheast

and southwest Yunnan Province. Because of the favorable effect of the sountheast monsoon and southwest monsoon, some tropical plants occur along the Gaoligong Mountains northward to Lushui, Fugong, and Gongshan, and also occur in southwest and southeast Yunnan. However, isolated by the ecological transition belt mainly consisting of the dry and hot valleys along the Yuanjiang River – Honghe River, these species hardly spread further northward. So many of the species living in the Gaoligong Mountains can only spread on the southwest side of the Ecological Diagonal (Figures 9: 2, 12: 1, 13 ~ 25).

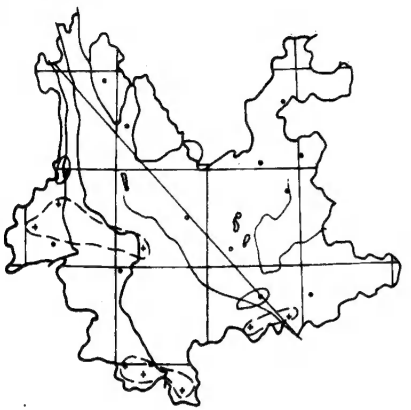

Fig.13 Southwest area of the Ecological Diagonal of species in Yunnan 1. *Amorphophallus nanus* (Lushui – Gejiu. 930 ~ 1200 m); 2. *Arisaema inkiangensis* (Baoshan, Jingdong – Menghai, Mengla, Jinghong – Jinping, Pingbian)

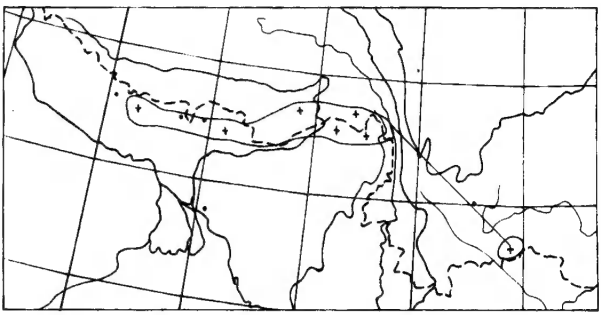

Fig.14 Disjuncted distribution of *Ilex intricate* in the Himalayas (Nepal, Bhutan, Sikkim, Tibet, north of Myanmar) and Yunnan (Gongshan – Malipo)

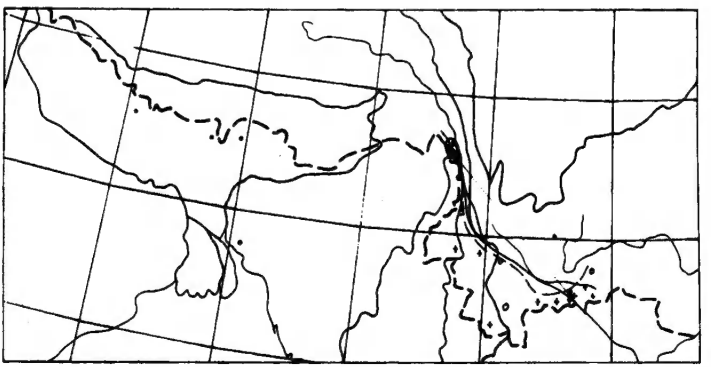

Fig.15 Southwest and south areas of the Ecological Diagonal of species in Yunnan

1. + *Piper glabricaule* (Gongshan, Fugong, Lushui, Longling, Jingdong, Fengqi, Xichou, Menghai, Lüchun, Jianshui, Mengzi, Pingbian, Jinping, Hekou, Wenshan, Malipo. 1200 ~ 1300 m)

2. ° *Piper nudibaccatum* (Gongshan, Lushui, Longlin, Menghai, Jingdong, Simao, Funing)

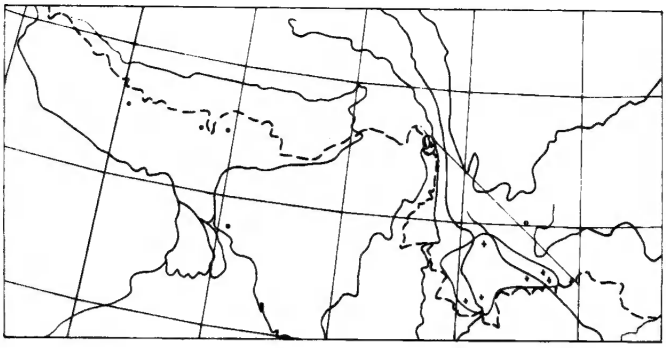

Fig. 16 Southwest area of the Ecological Diagonal of *Begonia tetragona* in Yunnan (Gongshan Donglongjiang, Cangyuan, Jingdong, Menghai, Jinghong, Mengla, Yuanyang, Lüchun, Mengzi, Pingbian, Malipo)

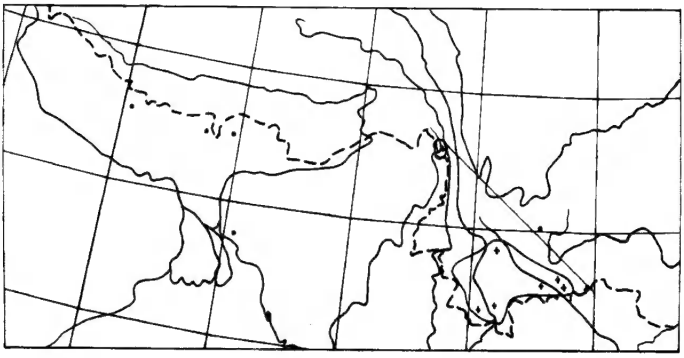

Fig. 17 Southwest and eoutheast areas of the Ecological Diagonal of *Begonia palmata* var. *henryi* in Yunnan

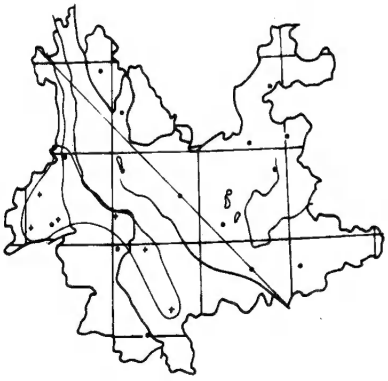

Fig. 18 Sounthwest area to the Ecological Diagonal of *Eurya jingtungensis* in Yunnan

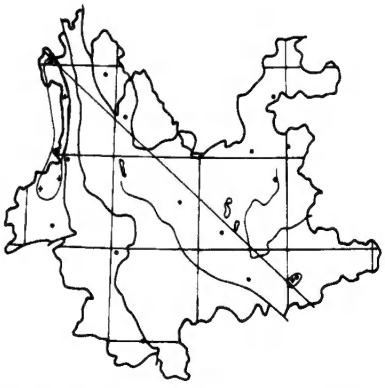

Fig. 19 Southwest and southeast areas of the Ecological Diagonal of *Schima sericans* in Yunnan

3.2.3 **Isolation effect of the Ecological Diagonal** The compositions of biota on both sides of the Yunnan Ecological Diagonal are different. The flora in northeast Yunnan is closely related to that in Central and East China. Neither the flora composition from Central and East China nor the flora in

northeast Yunnan can cross the Ecological Diagonal to southwest Yunnan. Also, many of the species generally growing in the west, south, and the southeast of Yunnan cannot go over the diagonal to the central part and northeast Yunnan. This is an isolation effect of the Ecological Diagonal. Figures 13 to 22 show 18 examples of the isolation effect.

Fig.20 Southwest area to Bio – diagonal line of species in Yunnan
1. + *Eurya yunnanensis* (Tengchong, Fengqi, Jingdong, YuanJiang, Xingping, Mengzi, Pingbian, Maguan, Wenshan. 1500 ~ 2800 m)
3. Δ*Aucuba yunnanensis* (Gongshan – Tengchong, Longling, Fengqin)

Fig.21 Northwest, southwest and southeast areas of the Ecological Diagonal of *Rourea caudata* in Yunnan (1300 ~ 1600 m)

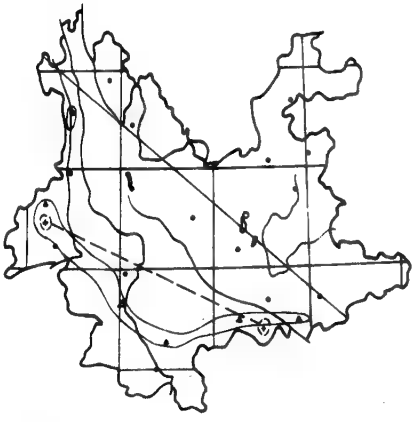

Fig.22 Southwest area the Ecological Diagonal of species in Yunnan
1. + *Pentapanax lexchenaultii* var. *simplex* (Tengchong – Jingping)
2. Δ*Schefflera macrophylla* (Fugong, Tengchong, Lincang, Simao, Pingbian, Lüchun)

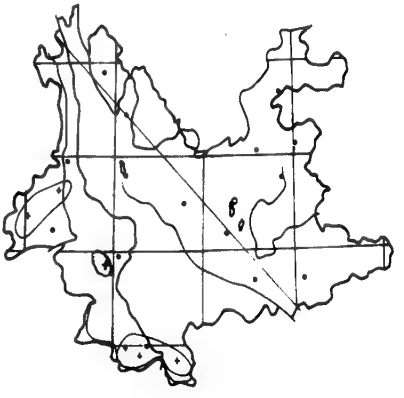

Fig.23 Southwest area of the Ecological Diagonal of *Costus oblongus* in Yunnan (Baoshan, Yingjiang, Lincang, Menghai, Jingdong, Mengla)

3.2.3.1 Isolation of flora with composition from East Himalayas About 50% of the plant species growing in the Gaoligong Mountains have a distribution that extends into the East Himalayas, but they cannot spread across the Ecological Diagonal from the southwest side to the northeast (Figures 15, 26,

27, 28, 29, 30)

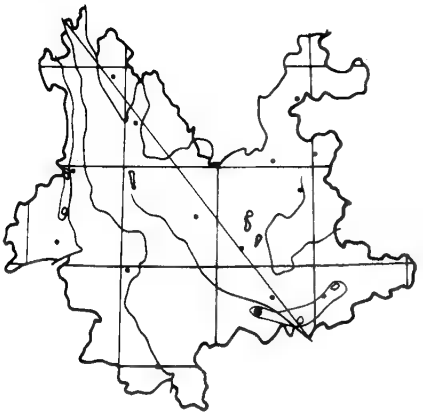

Fig.24 Southwest and southeast areas of Ecological Diagonal of *Typhonium calcicolum* in Yunnan (Lushui, Baoshan – Yuanyang, Hekou, Pingbian, Xichou)

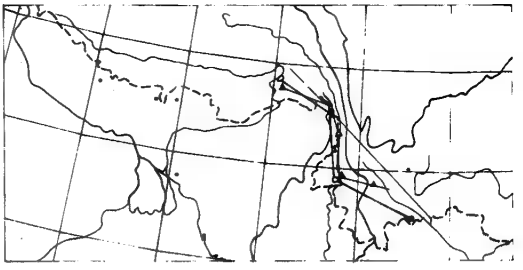

Fig.25 Disjunct areas in Tibet (Motuo) and the southwest area to Ecological Diagonal

1.° *Saurauia erythrocarpa* (Motuo – Gongshan, Longling, Jingping. 1300 ~ 1700 m)

2. △*Pilea auricularis* (Motuo – Gongshan, Fugong, Longling,, Jingdong)

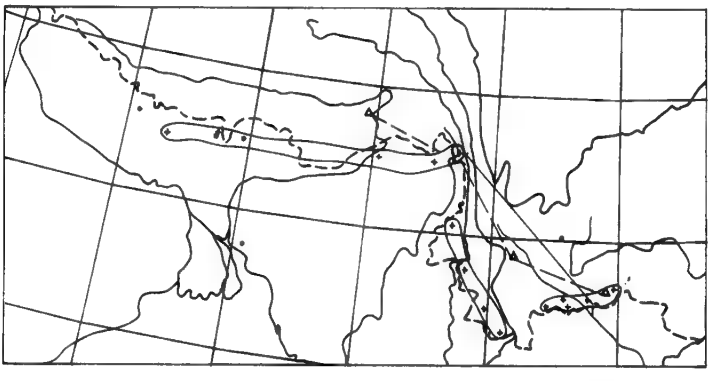

Fig.26 Distribtions to the nothwest, southwest, and southeast of the Ecological Diagonal

1. + *Elatostema dissectum* (Nepal, Sikkim, Assam of India, northern Myanmar, Gongshan Dulongjiang, Tengchong, Zhengkang, Lincang, Menghai, Yuanyang, Luchun, Jingping, Pingbian, Xichou, Malipo; Pingnan of Guangxi Province, eastern Guangdong Province); 2. △ *Elatostema tenuicaudatoides* (Motuo – Gongshan, Jingdong, Xichou)

3.2.3.2 Isolation of tropical species Many tropical species found in the Gaoligong Mountains also occur in the tropical areas of Asia and Africa. In Yunnan, they may spread northward to Gongshan (27° 45′N), but hardly go across the Ecological Diagonal to the Jingsha River valley at low latitude or to the central Yunnan Plateau. (Figures 31 ~ 35)

3.2.3.3 Isolation of endemic species Most of the species endemic to Yunnan growing in the Gaoligong Mountains have a distribution that extends to southwest Yunnan, but they cannot go across the diagonal to the central Yunnan Plateau (Figures 13:2, 18, 22:2).

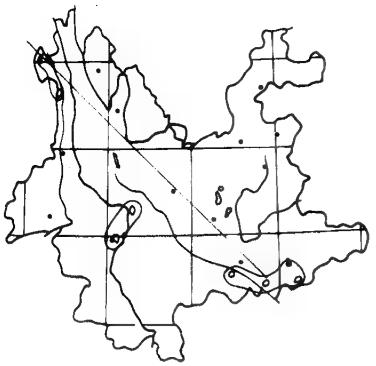

Fig.27　Southwest area of the Ecological Diagonal of *Saurauia polyneura* in Yunnan (Mutuo, Gongshan, Fugong, Jingdong, Lincang, Yuanyang, Pingbian, Wenshan, Maguan. 1300 ~ 2600 m)

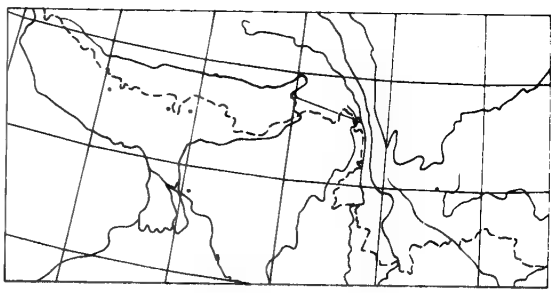

Fig.28　Disjuncted area Motuo – Gongshan of *Saurauia polyneura*

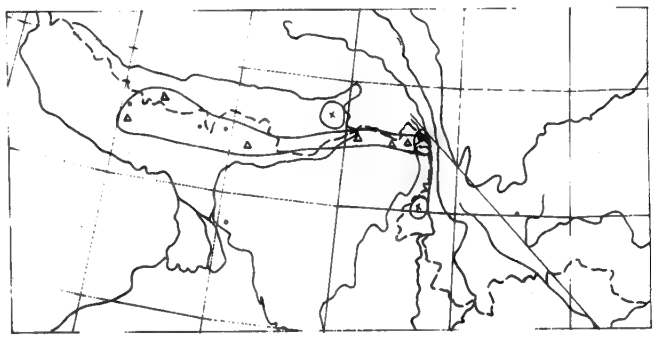

Fig.29　Disjuncted areas of the Motuo – Gaoligong Mountains (1) and Himalayan element limited in Gaoligong Mountains (2)

1. o *Ilex atrata* var. *wangii* (Motuo – Gongshan, Tengchong)

2. Δ *Ilex hookeri* (Nepal, Sikkim, Bhutan, NE India, northern Myanmar, Dingjie of Tibet, Gongshan)

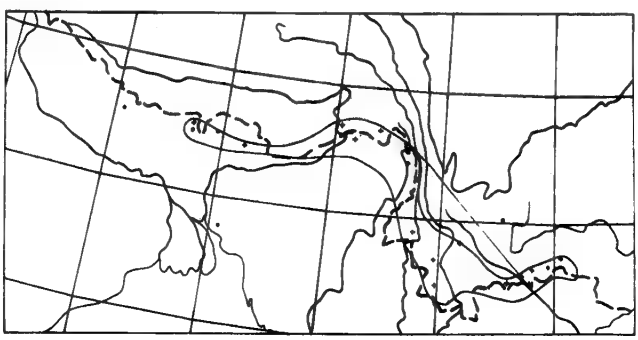

Fig.30　Disjunct between the Himalayas as well as southwest and sountheast of the Ecological Diagonal of *Alcimandra cathcartii* (Distribution listed in Table 3 ~ 4)

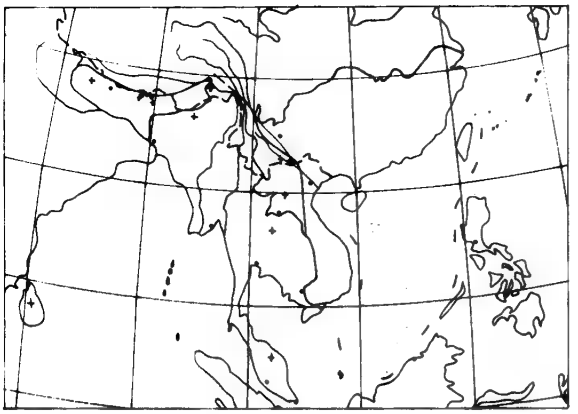

Fig.31 Southwest area of the Ecological Diagonal of Tropical Asia *Eurya acuminata* (Gongshan, Pingbian, Xichou)

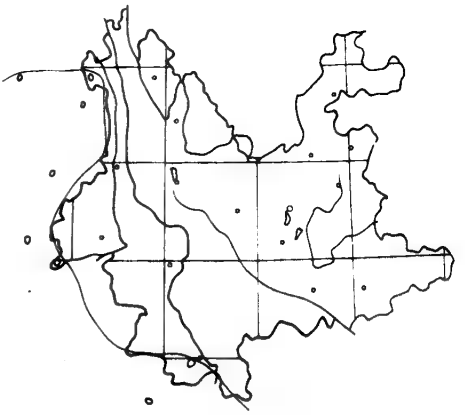

Fig.32 Distribution area of *Saurauia macrotritra* limited in Gaoligong Mountains in Yunnan (Myanmar, India, Malaysia; Gaoshan Donglongjiang, Ruili, Jingdong)

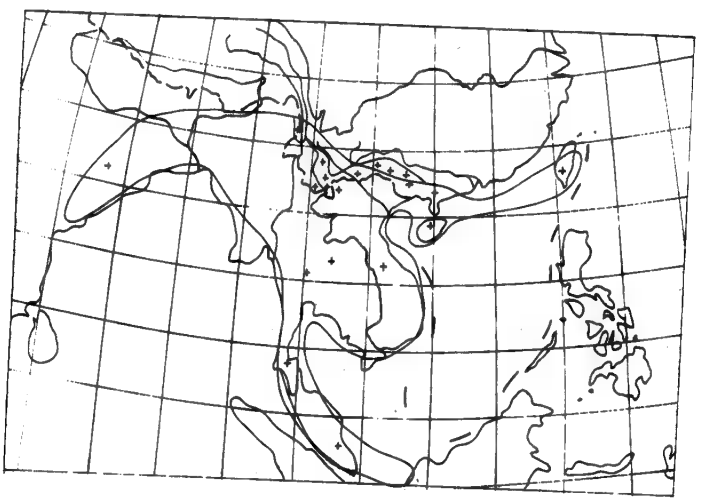

Fig.33 Distribution area of *Torenia flora* limited in south of Gaoligong Mountains in Yunnan

3.3 Variety of species in the Gaoligong Mountains

Although environmental conditions remained sufficiently unchanged after the displacement of the Shan – Malay Plate to allow some species persist unchanged, there were new ecological niches formed along with the neotectonics, and as a result many species differentiated. For example, of the more than 500 species of tropical *Syzygium* that are widely distributed in the Old World tropics, 33 species occur in the tropical region of Yunnan. Two species, *S. tetragonum* (a tropical Asian species) and *S. cumini* (widely distributed in the tropic and subtropics of Asia) occur in Lushui and Tengchong in the southen Gaoligong Mountains. In addition, there are two Yunnan tropical species, *S. forrestii* and *S. salwinense*. The existing environment to the north of Lushui is not suitable for most *Syzygium*, but an endemic species, *S. gongshanense* is adapted to the cold climate that occurs in the northern Gaoligong

Mountains, Another example is *Artocarpus* , which is also largely a tropical genus. Twelve species of *Artocarpus* occur in Hainan, Guangdong, and southern Yunnan. Although no doubt some tropical species once lived in the Gaoligong Mountains, as the original environment changed along with the displacement, the distribution area gradually moves southward. At present, only one endemic species, *A. gongshanensis*, still exists in the Dulong River area to the west of the Gaoligong Mountains. It is likely that the existing *Syzygium* and *Artocarpus* species in the Gaoligong Mountains are new species evolved from the tropical species, which is consistent with the Gaoligong Mountains was once being situated in the tropical zone. There are more than 80 species of *Agapetes* that occur in tropical areas of Asia, of which 40 occur China and 20 in Yunnan. In the Gaoligong Mountains there are 10 species and one variety, all of which except *A. angulata* (in the Dulong River area and north Myanmar) are endemic to the Gaoligong Moutains. Again this shows a largely tropical group that has evoloved into the more temperate region of the Gaoligong Mountains.

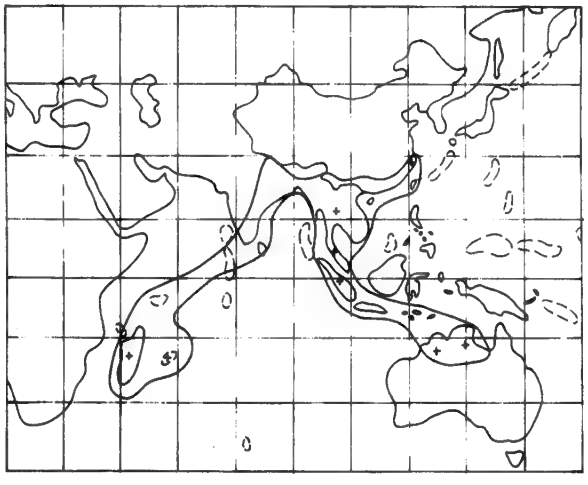

Fig.34 Distribution area of *Dianella ensifolia* limited to the southwest of the Ecological Diagonal (Yunnan: Lushui, Menghai, Jinghong, Mengla, and all counties in southeast Yunnan)

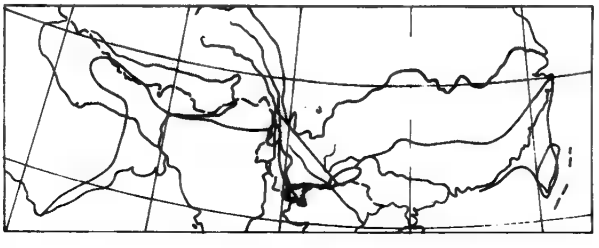

Fig.35 Distribution area of *Dianella ensifolia* in China

4 Biological effect of displacement of the Gaoligong Mountains of its fauna

4.1 Fish

Zhu (1979, 1987) and Chao (1981) carried out researches on occurrence, formation, and

evolution of fish species such as in the subfamily Sisoridae and the genus *Schizothorax* in the subfamily Schizothoracinae. Their research also gives an introduction to the geological history of this area. The research carried out by Wu and Wu (1992) demonstrate the biological effect of the neotectonics upon the fish community within a larger scope. The discussion of the fish fauna in the Gaoligong Mountains regions is base on these works. There are comparatively few fish species in the Gaoligong Mountains area, and there are very few species that occur in drainages on both the east and west side of the mountains. Of the 20 species in the Nujiang River and the 32 species in the Irrawaddy River, only 5 are common species in both rivers (Chen, 1995).

4.1.1 Tropical and temperate fish elements in the Gaoligong Mountain drainage In the drainage system of the Gaoligong Mountains there are 7 genera and 12 species of Barbinae which is mainly a tropical subfamily. These species of fish now live in the Irrawaddy River and the Nujiang River on both sides of the mountains. In the Nujiang River there are 6 endemic species, *Torhemispinus*, *Percocypris Pingi retrodorsalis*, *Barbades opisthoptera*, etc. which occur in the Baoshan and Luku areas. In the Irrawaddy River there are 3 endemic species, *T. qiaojiaensis*, *Barbodes margarianus* and *Garra qiaojuaensis*, which only occur in the Longjiang River and Daying River in Tengchong area. The other 3 species are wide spread with two extending to India and one to Xizang (Tibet). Fish belonging to the subfamily Schizothoracinae originated in Xizang and are adapting to cold water. In the Gaoligong Mountains there are 2 genera and 8 species in the two drainage systems. *Schizothorax nukiangensis* lives in the Nujiang River and occurs from Changdu to Luku. *Gymondiptychus integrigymnata* is only found in the Longjiang River within the Tengchong area. It can be seen from the above that the species of Barbidae and Schizothoracinae of different origins have found a suitable living conditions in the rivers. *Shizothorax meridionalis* and *Gymondiptychus integrigymnata* (the cold water group) live together with *T. qiaojuaensis* and *G. qiaojuaensis* (the warm water group) in the Longjiang River within the Tengchong area. This is an example of the fish community of oriental realm living together with that of palearctic realm in the Gaoligong Mountains area. The fish adapting to both cold and warm water can also be found in the Lushui and Nujiang rivers. If the Gaoligong Mountains had not moved northward, possibly the two different groups of fish might not occur together.

4.1.2 Various endemic fish species Along with displacement of the Gaoligong Mountains, high mountains rose with deeply cut gorges between them thus isolating the fish in each major drainage system. Any fish species that had been in common in these drainage system would now evolve separately resulting in the high amount of specific endemism. The fish in the Gaoligong Mountains area totals 47 species of which 27 are the endemic, amounting to 57% of the total. This is much higher than the percentage endemism for either species of seed plants or mammals probably reflecting the more limited pssibility for dispersal for fish. The distribution of the fish endemism in the Gaoligong Mountains has the following features: (1) The endemic species in the tributaries of the Irrawaddy River are quite different from those in the Nujiang River. There are 12 endemic species in the Nujiang River and 15 in tributaries of the Irrawaddy River. The fish communities in the two water systems are completely isolated from each other. (2) Most of the endemic species in the Gaoligong Mountains region belong to the

order Cyprinodontiformis. In the subfamily Barbinae the endemic species includes *Tor hemispinus* (in the Luku region of the Nujiang drainage), *T. qiaojuaensis* (in the Longjiang River in Tenchong), *Barbodes margarianus* (in the Tengchong and Tuantian regions of the Irrawaddy drainage) and *Barbodes opisthoptera* (in the Baoshan region of the Nujiang drainage). In the subfamily Labeonidae there are five species of which 4 are endemic, such as *Epalzeophynchus bicornis* (in the Luku and Baoshan regions of the Nujiang drainage). In the subfamily Schizothoracinae there are 8 species, all of which are endemic such as *Schizothorax nukiangensis* from Lushui upwards to Changdu along the Nujiang River. In the family Homalopteridae the endemic species *Heminmyzon nujiangensis* occur in the Luku region of the Nujiang River. In the order Siluriformis there are five endemic species in the family Sisoridae there are five endemic species such as *Exostoma labiatum* (in the Dulong and Daying rivers), *Glaridoglanis andersonii* (in the Chayu and Gulang) in the Irrawaddy drainage, and there are two endemic species, *Pareuchiloglanis gongshanensis* and *Pseudexostoma yunnanensis* both in the Laowo River in the Nujiang drainage.

4.1.3 Difference in fish species between the southern and northern river reaches After the displacement, the drainage system in the northern part of the Gaoligong Mountains moved to the temperate zone. On the east side of the mountains melted snow flows into the rivers from the Tibetan Plateau to the north resulting in the water temperature of the northern reaches of the Nujiang River being lower than in the southern reaches. The effect of this difference in water temperature on fish is a dividing line between two distinct fauna near Luku at 26°20′N with temperate fish only found to the north of this latitude such as *Nemachellus longus*, *N. vinciguerrae*, *N. pulyaenia*, *Botia histrionica*, *B. rostrata*, and *Misgurnus anguillicaudatus*. The last in this list is widely distributed in East Asia. Twenty species, or 60% of the 29 species in the Nujiang River are living within the reaches to the south of Luku. To the north of 26°10′N there are very few species. The pattern in the Irrawaddy drainage is more complicated and less well studied because much of east side of the Gaoligong Mountains is in Myanmar and also most of it does not drain from the Tibetan Plateau. However, a similar patter between north and south also exists. For example, 22 species, or 96% of the 33 species in the Irrawaddy in the Gaoligong Mountains area occur south of 26°10′N with only 6 cold water fish species occur to the north such as *Schizothorax nukiangensis* and *S. gongshanensis* (in the Nujiang River), *S. dulongensis* (in the Dulong and the Piama rivers), *Exostoma labiatum* (in the Dulong and Daying rivers), and *Glaridoglanis andersonii* (in the Chayu River and the Guland River). The fish occurring to the north are adapted to cold fast moving water while those to the south are adapted to warmer slow moving water. In the Gaoligong Mountains area some groups that are characteristic of one these types of environments have evolved species adapted to the other. For example, the genus *Schizothorax* mostly occurs in cold water, but the two endemic species *S. griseus*, *S. meridionalis* in the Irrawaddy drainage are adapted to the warmer slow moving water of the Longjiang River within the Tengchong area. In Contrast members of the family Sisoridae characteristically occur in warmer slow moving water but in the Irrawaddy drainage has evolved species that occur in cold fast moving water such as *Exostoma labiatum* (in the Dulong and the Daying rivers) and *Glaridonglanis andersonii* (in the

Chayu and the Gulang rivers).

4.2 Mammals

The discussion of the mammal fauna in the Gaoligong Mountains regions is based on research by Wang (1982, 1985, 1989, 1995) and an analysis of the impacts of the Shan – Malay Plate displacement on mammalian diversity.

Because of the long north – south extent of the Gaoligong Mountains, the relatively intact state of the vegetation and the diversity climatic regions (including tropical, subtropical, temperate, and alpine), a large number of mammalian species occur in the region. For example, in the state natural reserve of 8 333 ha at the southern part of the Gaoligong Mountains, there are 115 taxa of mammals which is 20.1% of the total in China and 41.4% in Yunnan Province. This is not only the highest mammalian diversity found in Yunnan but the highest in all of China.

The biological isolation effect due to the plate displacement and rotation effecting the evolution of the plant communities and flora resulted in the Gaoligong Mountains having a diversity of ecological niches for mammals. As a result there are many of endemic subspecies. For instance, there are 77 endemic subspecies in 25 families recorded in the Gaoligong Mountains. In the state natural reserve about 1/3 of the mammal species are endemic, and over half of the species have produced endemic subspecies. This is the highest area of mammalian endemism in China (Wang, 1995).

The changes in the flora of the Gaoligong Mountains from north to south and vegetational zonation with elevation have resulted in a diversity of habitats for mammals. In addition the isolating factors discussed for plants above also affect the mammal populations resulting in the same sorts of biogeographic relations in plants resulting in affinities to the East Himalayas, tropical Asia, and widespread species.

5 Conclusions

The Himalayas orogenic movement occuring in the middle to late period of Tertiary Period produced the biological effects throughout this part of the world. The biological effect of the Shan – Malay Plate displacement concentrated on the Gaoligong Mountains is only part of the biological effect. This large scale latest neotectonic movement resulted in tremendous effects in such areas as the southern part of the Himalayas, the Qinghai – Tibet Plateau, Central Asia, the three – river conjunction area in northwestern Yunnan, and the Yunnan Plateau. The vertical displacement resulted in tremendous physical and climatic changes in all of these regions and resulted in many new habitats that allowed for the in explosive diversification of many plant groups into these new habitats. The combined vertical and horizontal displacement cause isolating factors such as the Yuanjiang River – Honghe River valley along the great Honghe Fracture and the Ailao Mountain system in parallel to the valley, which make up the important NNW – SSE ecological transition belt in Yunnan. On the northwest side of this Ecological Diagonal is the isolated region of the Gaoligong Mountains.

The area from Myanmar to northeastern India, southern Xizang, Bhutan, and eastern Nepal are all part of the same biogeographic region as the Gaoligong Mountains. The distribution pattern for both plants and animals in this whole region results from the neotectonic vertical and horizontal displace-

ment. Our hypotesis is that the Gaoligong Mountains is original center for the flora and fauna which became a distinct biogeographic region as a result of the tectonic displacement and isolation discussed in this paper. This Gaoligong theory predicts that plant and animal groups to the north and east into the East Himalayas should be more derivative and there should be a higher concentration of more ancestral taxa in the Gaoligong region. Because of inaccessibility of this area to north and east from the northern end of the Gaoligong Mountains through to Bhutan and eastern Nepal, there are limited data to test this theory. We hope that future biogeographic surveys into this area will supply the biogeographic and biological data necessary to test this theory.

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